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MACHINE TIMING lNTEGRATED INTO AN EXPERT CAD CAE SYSTEM FOR COLD FORGING TECHNOLOGY

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ABSTRACT

Current practice in timing and setting-up multi-station forging machines involves considerable time and effort from skilled manpower. Integrating this activity into a computerized environment for design and engineering of cold forged products ensures benefits such as deskilling of the task and reduction of lead time to manufacture.

The paper describes a computer-aided procedure for liming and setting up of cold forging multi-station machines, which is a module of an expert CAD/CAE system integrating all activities in planning the cold forging process. The module is based on a 3-D solid representation of the objects moving in the working area and a kinematic model of a number of different multi-station presses. The user is assisted in identifying suitable timing conditions for the different stages of the timing and setting up task. Capabilities of the module include automatic collision check, collision avoidance suggestions and integrated CAD-procedure for the design of non-standard grippers.

1. INTRODUCTION

A suitable press is a basic requirement for the technical and economic success in any forging production [1]. In the automotive industry, where large lot sizes and high quantity production prevail, modern mechanical multi-station machines with automatic work transfer between stations (henceforth called mechanical transferpresses) are often preferred. High production rates, stable quality and precision of the forged product and some energy saving, mainly due to avoiding intermediate annealing, are well-known advantages leading to an increasing use of this category of presses.

Timing a mechanical transfer-press requires a complete co-ordination of the workstation actions with the gripping and transfer system to be accomplished. Such a task needs considerable time and effort of skilled personnel and is an essential part of the workplanning for the forging process which includes the design of preforgings and tools.

Recent contributions to the development of computer based systems for forging confirm the effectiveness of computerized techniques in facilitating, rationalizing and integrating the design and engineering phases in the manufacturing cycle of forgings [2-10].

This paper presents the main elements of a computerized procedure for timing of mechanical transfer-presses which is intended as a module of a CAD/ CAE system for the complete design and planning of the cold forging process [11]. Fig. 1 shows the functional architecture of the overall system.

The timing procedure described represents some progress in the work presented previously [4 and 5]. The procedure is integrated with the CAD/CAE system and its capabilities have been extended to permit the timing of different classes of horizontal and vertical presses.

2 MECHANICAL TRANSFER-PRESSES AND THE TIMING PRQBLEM

On the basis of their architecture mechanical transfer-presses can be distinguished into (i) horizontal and (ii) vertical presses. They can be equipped with different types of [13-14] for handling the partially completed parts among the different stations. The most usual transfer and gripping devices are illustrated in Fig. 2.

The transfer system is always synchronous, with a gripper unit for each pair of adjacent workstations, the actions of the gripper fingers and the transfer motion being simultaneous. Horizontal presses can be equipped with the transfer mechanisms A, B, C and D of Fig. 2, whereas vertical presses utilize the device E or a devoted external manipulator.

The transfer mechanism must not only move the blanks from the station from which they have been ejected to the subsequent one, but must also locate and hold the blanks in the correct position until the punches impact and push them into the die-cavities.

Accordingly, gripping and transfer of the blanks require to be coordinated, with split-second timing and accuracy, with workstation actions such as ejection of the cut-off at the push-out station and die-side and punch-side ejection of blanks. Positions and stroke lengths are assigned to the transfer and gripping system as well as the ejection devices. This must be done in such a way to avoid typical problems, such as improperly gripped blanks, dropping or canting of the blanks when pushed into the dies and fingers colliding against the blanks or the punches. Stroke length and position for each device are controlled by steplessly and individually adjustable cams. The timing procedure is, therefore, part of planning the forging process, contributing to the check of the forging sequence design for producibility on the candidate machine. Sometimes a correct timing can not be actuated and partial redesign of tools or complete revision of the preform sequence can be required.

In current practice, most of the activities involved in machine timing are performed together with the machine setting up at the site of the machine. Thus, the non-operational contribution to the manufacturing lead-time is increased and the producibility check postponed to production trials in the shop-floor.

An appropriate timing is accomplished at the end of a trial-and-error procedure using the real machine and related documents, such as the travel/time diagram (a simplified example is given in Fig. 5), the tool-set assembly and the finger-path diagram.

3. THE CAE MOQULE FOR TIMING

The CAE module for timing has been developed in order to permit:

- verifying a forging sequence for producibility on a specific transfer press,
- determining a collision-free timing at every station of the press,
- integrating the timing task with the other concurrent engineering activities in planning the forging process.

The major benefit expected through the use of this module is that a large part of the work concerning the setting up of the machine is removed from the shop floor, as the setter is presented with acceptable timing data for the machine. In details advantages relevant to the use of a computerized procedure can be summarized as follows:

- less interference with production and reduced set up times. The most labour intensive tasks are performed away from the machine which can be kept in operation producing other parts and they are transferred to the domain of the planner. Timing sheets are prepared by the planner more quickly, allowing the set-up to be performed more efficiently;

- incorporation of the collision check. The module detects automatically any collision among blanks, tools and grippers and offers suggestions to avoid them.

3.1 The Module Architecture and Integration

The module works as an interactive "trial and error" procedure implemented in a commercial CAD-system. The functional architecture of the module (see the scheme of Fig. 3) has been designed in such a way to cover all the activities leading to a complete and correct timing work plan of the machine.

These activities include:

- checking the sequence for producibility on the selected press, through a systematic comparison of press and product characteristics;
- selecting standard grippers or designing a new set of fingers;
- determining suitable grasping positions of the blanks;
- deciding gripper opening and closing for each pair of stations served by the same gripper;
- detecting possible collisions among tools, fingers and blanks and suggesting measures for collision avoidance;
- printing out the timing data sheet at the end of the timing session.

After the consistency check between process requirements and machine features has been accomplished, all the following activities until the timing validation are performed in turn for each pair of adjacent stations served by the same gripping and transferring unit, starting [from the push-out station up to that where the finished blank is discharged. For each pair of stations, the use of ejection brake and the value of the ejection protrusion are decided. The following basic operations are then timed:

- gripper opening at the 2-nd station,
- punch-side ejection at the 2-nd station,
- die-side ejection at the 2-nd station,
- gripper closing at the 1-st station,

this sequence permitting the timing to be achieved in a minimum number of try-outs.

The module integration into the CAD/CAE system is directly related to the interaction between the three environments of which the system consists:

- the CAD environment, where geometric models arc generated, edited and stored and graphical facilities are available, as well,
- the CAE environment, consisting of the application programs, and
- the central DB and DBMS, for all the data making the CAE modules working and that cannot be stored in the database of the CAD system.

The scheme of Fig. 4 shows the functional requirements in the different environments of the timing module.

Interaction between the CAD system and the CAE modules is at a functional level, through the call of a library of dummy routines handling each of the CAD functions required by the CAE modules. When the CAE modules are linked to a new CAD system, the only requirement is the extension of the dummy routine library.

The integration between the CAE modules is through the central database and the CAD system data base respectively for alphanumeric and graphical data. The query language to the central DB from CAE modules uses SQL calls.

3.2 The Machine Model

The simulation of motions utilizes 3-D models (C.S.G.-, boundary- or surface- models) of the objects moving in the working area and is based on a kinematic model of the machine which permits to evaluate at each step of the simulation the positions of the objects.

This model is derived from the travel-time diagrams of the machine, which are usually furnished together with the machine and currently used by sequence designer and machine operator to perform the timing. These diagrams (an example is in Fig. 5) give for each tool (punches, ejectors, grippers, transfer. device and pressrarn) a family of curves. Each family describes the position of the corresponding tool as a function of both the crankshaft angle and an adjusting parameter (e.g. the ejection stroke for the die-side ejector).

A general representation of these diagrams, suitable to every class of presses, is based on a piecewise polynomial approximation, which uses cubic segments and ensures the first derivative continuity.

4. EXAMPLE OF A WORKING SESSION

Some screens and printouts are given relevant to a working session for timing an Hatebur Coldmatic AKP4-5 horizontal machine [15]. The forging sequence is shown in Fig. 6 and in this example the CAD platform is EUCLID-IS of Matra Datavision. Fig. 7 refers to the timing stage where the user decides the pressrarn position at which the gripper starts to open. Fig. 8 shows a collision detected between the gripper and the blank during the gripper opening at the 6th station. Two alternative measures suggested to avoid this collision phenomena are (i) changing the gripper geometry and (ii) anticipating the gripper opening. According to the two measures, the user goes. back in the timing and modifies the gripper shape or the pressram angle at which gripper opening starts. The timing-data sheet relevant to the correct timing is printed out at the end of the working session. Fig. 9 shows the part concerning the last pair of stations.

5. CONCLUDING REMARKS

The new elements of a computerized procedure for timing of mechanical multi-station machines with automatic transfer between stations have been presented. The procedure, which is a CAE module of an integrated CAD/CAE system for the complete design and planning of the cold forging process, assists the user in identifying suitable timing conditions for the different stages of the timing and setting-up tasks, including collision check and design of non-standard grippers. In addition to advantages such as increased efficiency and reduced time in preparing timing sheets, the use of the procedure has the important implication that a large part of the work concerning the producibility check of the product and the machine preparation are removed from the shop floor and integrated with the process design activities.

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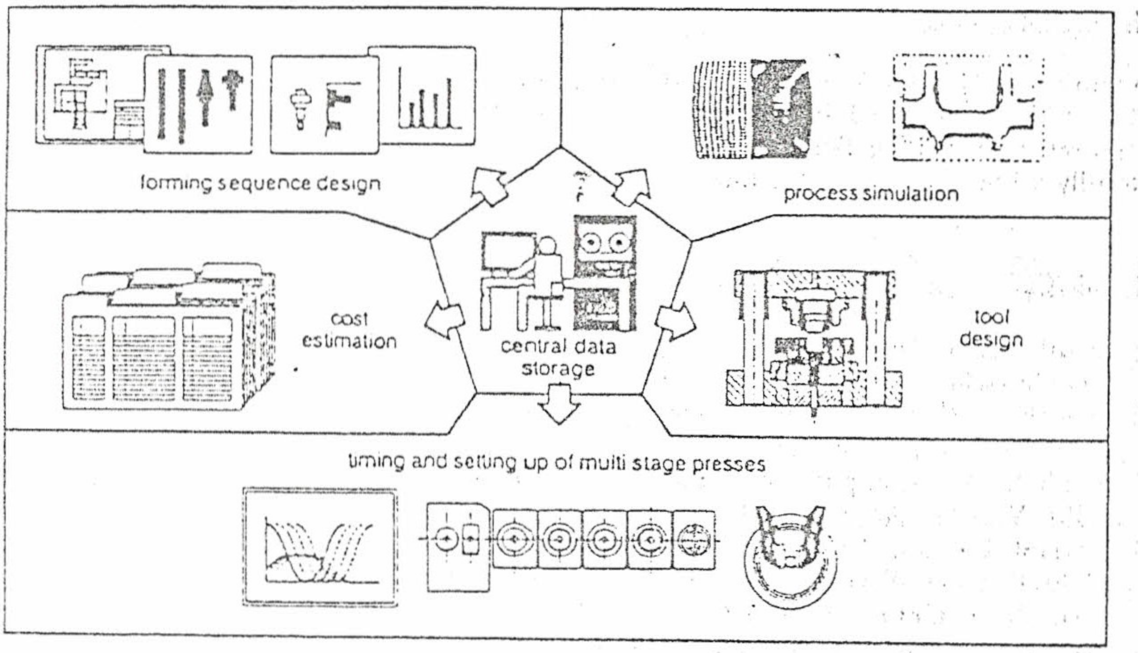

Fig. 1. The Integrated CAD/ CAE System for Cold Forging Technology.

Fig. 2. Typical transfer devices in mechanical transfer-presses.

Fig. 3. Structure of the Timing Module.

PRESS TIMING MODULE

SPECIFICATION OF FUNCTIONAL REQUIREMENTS
IN THE DIFFERENT ENVIRONMENTS

	Environment			
Functionalities	CAD	Graph.	CAE	DB
press-data retrieval				●
punch, die and gripper retrieval	●			
press simulation			●	
timing-diagram display		●		
animation organization	●			
animation display	●			
collision check	●			
timing-table display		●		
timing-table storage				●

Fig. 4 . Functional requirements in the different environments of the Timing Module.

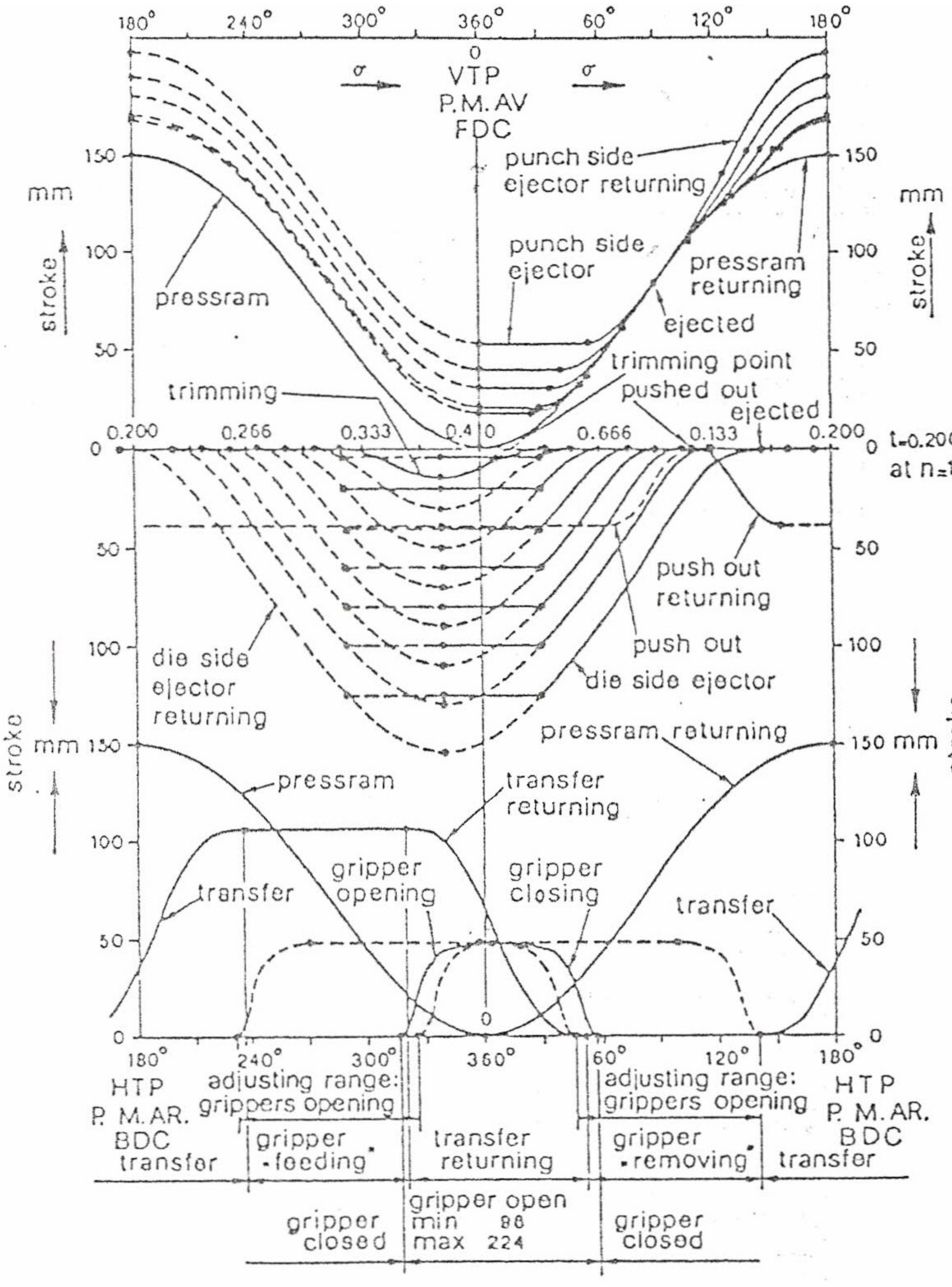

Fig. 5. The travel-time diagrams of an Hatebur Coldmatic AKP4-S machine.

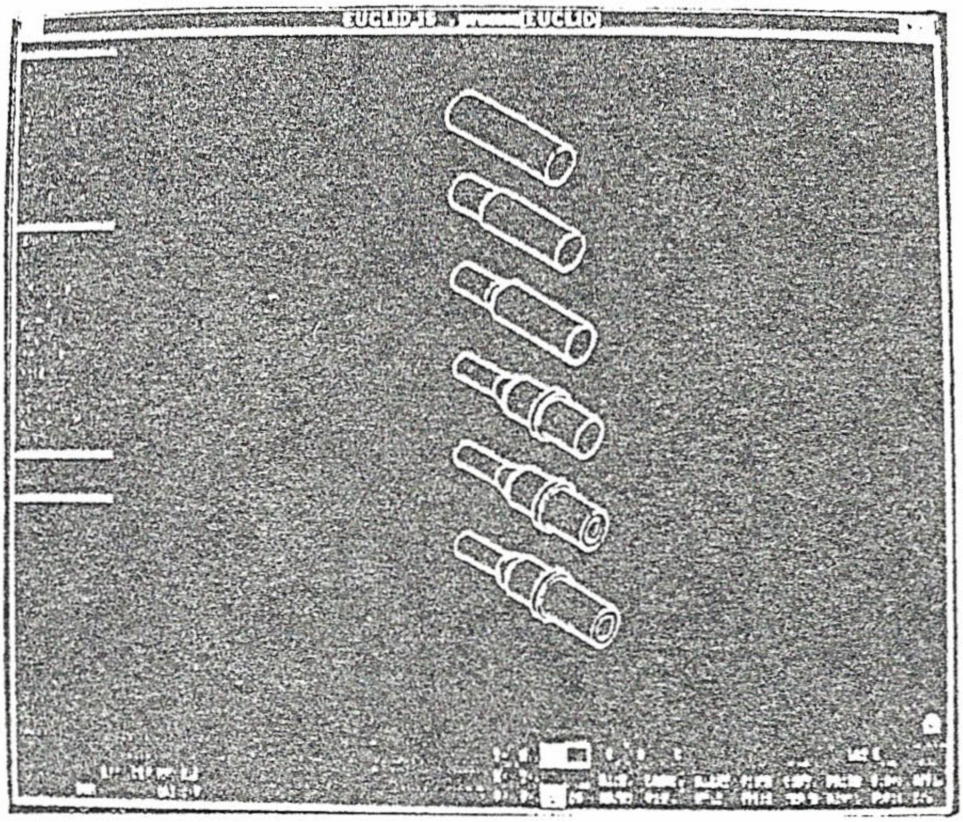

Fig. 6. The forging sequence.

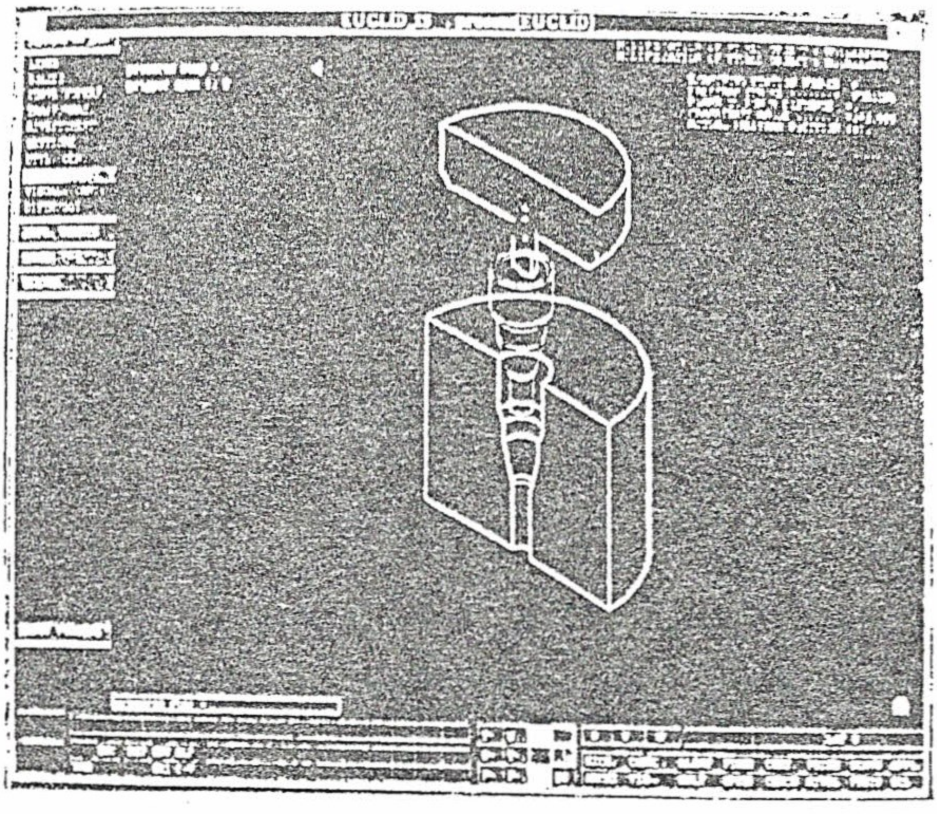

Fig. 7. The gripper opening stage.

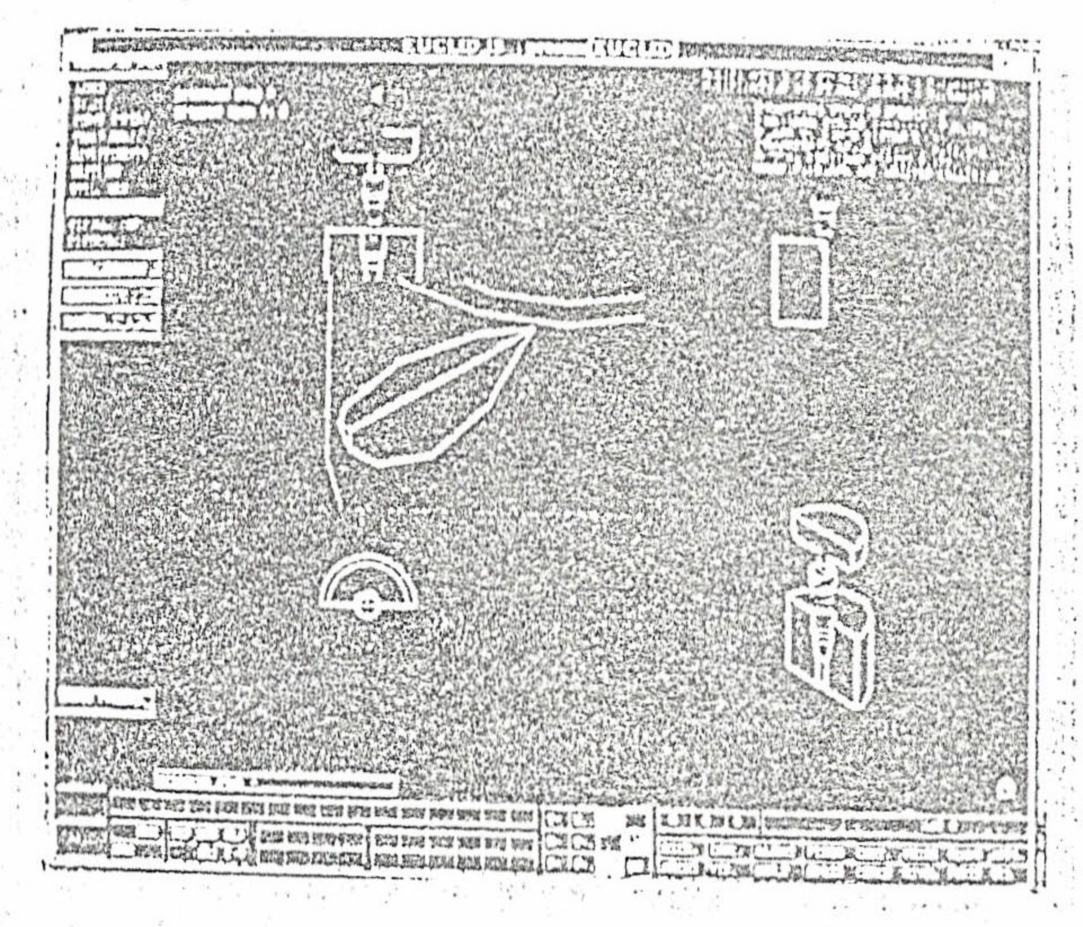

Fig. 8. The collision detection.

TIMING DATA SHEET

PART NAME ALB_1
PRESS AKP45 HATEBUR

FIRST STATION CONSIDERED IN GRIPPER OPENING : 5
LAST STATION CONSIDERED IN GRIPPER OPENING : 6

GRIPPERS AND TRANSFER

Gripper Nb.	Left Finger CODE	Right Finger CODE	Depth [mm]	Opening Angle [°]	Closing Angle [°]
4	HG1L222630	HG1R222630	30.00	284.32	86.36
5	HG1L222630	HG1R222630	40.00	265.42	72.07

EJECTORS

DIE SIDE

Station Nb.	Ejector Brake	Ejection Stroke [mm]	Ejection Angle [°]	Clearance [mm]
4	NO	75.00	97.02	2.80
5	NO	82.80	105.30	2.80
6	YES	0.00	0.00	2.60

PUNCH SIDE

Station Nb.	Brake Condition	Ejection Stroke [mm]	Ejection Angle [°]	Clearance [mm]
4		0.00	0.00	
5		0.00	0.00	

Fig. 9. The timing data sheet of the 5th and 6th station.